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Integration of Seaweed Cultivation, Agricultural and Non-Enterprises: A Comparative Analysis of Livelihood Diversification in Takalar Regency, South Sulawesi

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Seaweed cultivation plays a strategic role in the livelihoods of coastal communities, enhancing food security, generating income, and providing employment. Takalar Regency, in South Sulawesi Province, is a coastal area with high potential for seaweed cultivation. However, price fluctuations, climate change, and low product availability have encouraged farmers to diversify their livelihoods. This study analyzes the patterns of livelihood diversification among 41 seaweed-farming households across six hamlets in Laikang Village, using thematic qualitative case studies. Six diversification patterns were identified: (1) seaweed cultivation; (2) seaweed and agriculture; (3) seaweed and fisheries; (4) seaweed with agriculture and fisheries; (5) seaweed, agriculture, and non-agriculture; (6) seaweed and non-agriculture. Patterns of seaweed cultivation, combined with agriculture and fisheries, primarily rely on natural, human, and financial capital, reflecting a stronger integration of livelihood assets. On the other hand, patterns involving non-agricultural businesses require social, human, and financial capital. Furthermore, most diversification patterns have not been integrated into farmer groups, resulting in limited access to government assistance and training programs. Diversification and investment are key strategies in addressing economic and social vulnerability. The study highlights the importance of strengthening institutional support, capacity building, and market access to promote sustainable seaweed-based livelihoods in coastal communities.

Keywords: Aquaculture, algae, *Gracilaria* sp., livelihood diversification; seaweed cultivation; sustainable livelihoods; rural resilience.

INTRODUCTION

The fisheries and aquaculture sector plays a dual strategic role, supplying raw materials for upstream industries while supporting downstream exports (Alemu et al., 2023). This sector significantly contributes to improving the welfare of coastal communities. One key aquaculture product, seaweed (an algae plant), is cultivated by taking its young spores as seeds (Billing et al., 2021). In Indonesia, seaweed production is projected to reach 10.8 million tons by 2024, dominated by *Gracilaria* sp. and *Kappaphycus alvarezii* (formerly *Eucheuma cottonii*), which serve as raw materials for food, cosmetics, medicine, paper, paint, and fertilizer (Fisheris, 2024). Seaweed is chosen because of its easy cultivation technology, quick return on investment, and ability to operate alongside other businesses. However, cultivation is highly dependent on natural conditions and price fluctuations, and some seaweed farmers have chosen to withdraw due to competition from beach-based tourism operations (Mariño et al., 2019). Laikang Village, Takalar Regency, is the site of seaweed cultivation in South Sulawesi. This village has excellent potential for seaweed cultivation, but prices are highly volatile. In January 2024, IDR 14,000 per kilogram. It then fell again to IDR 11,000 per kilogram in May and June 2024, before rising to IDR 13,000 per kilogram in November and December 2024. While harvesting at 40 days yields higher quality, higher-priced products, farmers often employ rapid-harvesting methods (40 days) to mitigate crop failure

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caused by climate change. Almost every household cultivates seaweed on a small scale using simple technology and family labor, particularly the labor of wives and children, reflecting the principle that family-based farming supports sustainability (Chmieliński et al., 2023). Given production constraints, environmental risks, and low income, many farmers diversify into agriculture, fisheries, or small non-farm businesses to stabilize household earnings. Seaweed farmers with land also engage in agriculture (rice, corn, green beans) or fish catching to meet their needs. Conversely, those who do not own agricultural land are involved in non-agricultural businesses, such as grocery stores, seaweed production facilities, and workshops. According to Conway and Chambers (1991), sustainable livelihoods are characterized by resilience to stress and the ability to secure opportunities for future generations. The optimal use and combination of livelihood assets—human, natural, physical, social, and financial—form the foundation for effective livelihood strategies (Kumar & Rai, 2021; Bhowmik et al., 2021). Livelihood diversification is widely recognized as a sustainability mechanism that promotes food security and reduces vulnerability to socio-economic and environmental shocks (Saboori et al., 2023). It allows farmers to overcome financial constraints, enhance technology adoption (Musyoki et al., 2022), balance labor utilization throughout the year (Holmelin, 2021), and improve overall household welfare (de Souza Celente et al., 2023). Diversification thus serves as both a coping and adaptive strategy, especially for communities dependent on climate-sensitive sectors (Stacey et al., 2021; Ellis & Freeman, 2004). Empirically, diversification improves income stability, welfare, and food security while strengthening biodiversity (Shiiba et al., 2022; Larson et al., 2021).

However, existing research seldom focuses on seaweed-based livelihood diversification, despite its growing importance in coastal economies. Given that most seaweed farmers in Takalar live on modest, unstable incomes, understanding how they diversify their livelihoods is crucial to improving resilience. Diversification represents a core strategy for sustaining and strengthening household livelihood systems under environmental and economic stress. Comparatively analyze the configuration of livelihood assets, strategies, and the influence of social structures, interactions, and vulnerability contexts in seaweed-farming households. This study employs a Sustainable Livelihoods Framework (SLF) to analyze their livelihood strategies comparatively.

MATERIALS AND METHODS

This study was conducted in Laikang Village, Mangarabombang Subdistrict, Takalar Regency, South Sulawesi (Figure 1). Laikang is a coastal village located at the southern tip, bordering Je'neponto Regency and the Flores Sea. The town covers approximately 19.6 km², has a tropical climate, and experiences distinct dry and rainy seasons. Most of the population (70%) are seaweed farmers, with the rest consisting of farmers, fishermen, traders, and others.

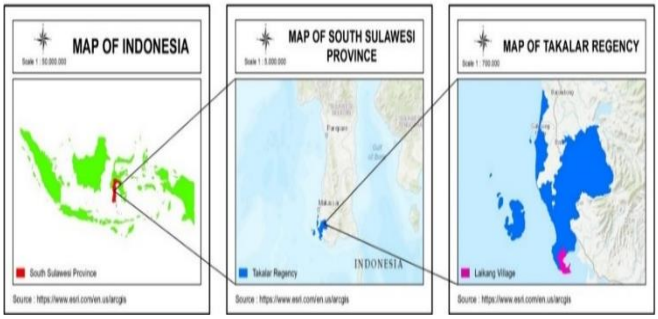

Figure 1. Research Location.

The case study approach was used in this research. This technique was chosen to enable researchers to interact intensively in a social setting, where seaweed cultivators utilize their livelihood assets through various strategies in different vulnerability contexts to achieve sustainable livelihood outcomes. The case unit is a village; it is seen as a contemporary, limited system that has developed over time. This type of case study is an instrumental case study, where a case is studied as an instrument to explain the empirical reality of a concept from the theory (Stake, 2014; Nan Lin, 2020). In this case, the idea of the alimony system.

The collection techniques used were in-depth interviews, observations, and document studies. An in-depth interview is a recurring encounter with an informant that involves a conversation (Creswell & Poth, 2013). The focus of the discussion in this interview is (1) the assets of the livelihood that are mastered, (2) the livelihood strategy (livelihood strategy) pursued, (3) The influence of social structures and processes on the implementation of livelihood strategies, (4) Context of vulnerability (vulnerability context) faced in the utilization of alimony assets which are shocking (shock), trends, and seasonality (seasonality); (5) Income of alimony (livelihood outcome) in the form of increasing income, improving living welfare and the sustainability of alimony assets between generations. Each interview session lasts 50-90 minutes. Our observations were made while participating in several seaweed cultivator activities, including installing rope stretches, tying seedlings to them, and harvesting. Some of our observations were made without participating in their activities. We conducted a document review of their records, including the length of the rope stretch, the number of seeds, production volume, sales price, and other relevant details. Data collection involved 41 seaweed cultivators selected through snowball sampling, a method used to identify individuals with specific characteristics that align with the study's focus. They consist of seaweed cultivation; seaweed cultivators who diversify into fishery activities; seaweed cultivators who diversify into agricultural activities; seaweed

cultivators who diversify into agricultural and fishery activities; seaweed cultivators who diversify into non-agricultural activities.

We analyzed the data in four stages using the Stake (1995) Method. The first stage involved categorical aggregation, which entailed grouping the livelihood system data into several categories, ranging from a single livelihood system for seaweed cultivation to the most diverse (seaweed and farming, seaweed and fishing, seaweed with agriculture and fishing, and seaweed and non-farming). We also categorized livelihood system assets (human, natural, social, equipment, and financial capital) within each category, assigning scores from 1 (lowest) to 5 (highest). The second stage involved direct interpretation, in which we assigned meaning to the data, particularly in relation to their livelihood strategies. The third stage, pattern formation, consists of analyzing the compatibility among categories to identify relationships, particularly among livelihood assets, techniques, and outcomes. The fourth stage is naturalistic generalization, which involves concluding cases that can be applied to similar cases. In creating categories or thematic analysis, we used NVivo version 12, which assists in coding, organizing, sorting, and visualizing data.

RESULTS

Pattern of Diversification of Seaweed Cultivators

***Seaweed as a Single Maintenance*:** Three informants from the villages of Laikang, Boddia, and Puntondo. Farmers in Puntondo village do not have cultivation land. Due to limited available land, cultivation activities are carried out in the Panyangkallang village area, located on the border between the Takalar and Jeneponto districts. Access to the cultivation site requires a 30-minute trip, which increases operational costs (about half a liter of diesel fuel per trip). The type of seaweed cultivated in Boddia village is Spinosum, which is used in both the dry and rainy seasons. This species is less expensive than *Euchema cottonii*, making it more economical for farmers with limited capital. The selling price ranges from IDR 3,000 to IDR 8,000 per kilogram, depending on the product's quality. However, it was found that farmers in Laikang use both types depending on the season, while farmers in Puntondo choose Cottonii year-round because it is considered a superior seed. Their main capital is the potential of the sea. However, due to the remote location of the cultivation, production costs also increase; therefore, natural capital is given a score of 3. Regarding human capital, their educational background is generally at the elementary and junior high school levels, and their cultivation experience ranges from two to ten years. They are not yet members of a farmer group, so they have not received guidance from extension workers. This aspect is also scored 3. Farmers utilize financial capital through financial institutions, including BRI, microfinance institutions (such as PNM), and collector traders. They do not have savings for business capital, so they are given a score of 4. The equipment used includes used boats, bottles as floats, ropes to tie seeds, and tarpaulins for drying. Although simple, this equipment is sufficient to support cultivation activities. They buy used boats for the efficient transportation of seaweed to be planted and harvested. This aligns with Crawford's (2002) explanation that seaweed cultivation was developed as a livelihood because it requires only simple equipment. Therefore, physical capital is given the highest score of 5. Finally, regarding social capital, their relationships are limited to collectors, traders, and women involved in seedling activities. There are no relationships or networks with cultivation groups, extension officers, cooperatives, or the processing industry. This condition reflects the weakness of social networks, which impacts limited access to information and is therefore assigned a score of 2. The combination of capital assets is illustrated in Figure 2.

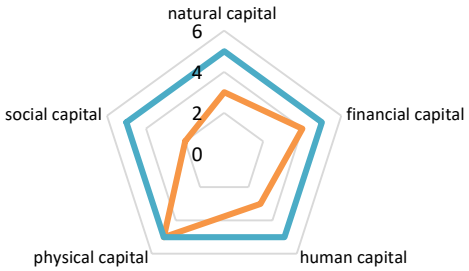

Figure 2. A combination of the use of Single Pattern alimony assets.

I focus on this business because it is promising, and there is no other option besides seaweed. Loans in the name of (mekar) organized by the National Community Loan (PNM) to purchase used boats made of wood that can be used (ADS. Seaweed Farmers).

This livelihood strategy, carried out by households, focuses on seaweed cultivation. However, during implementation, wives participate in the seedling process for their own family businesses and work in other households engaged in seaweed cultivation. This reflects the application of a dual maintenance strategy in households. Wives work as seedling workers, with an average wage of IDR 3,000 per stretch of rope. Income from the main business is used to meet basic needs, such as providing food, funding the company, and financing children's education. Meanwhile, the wife's agricultural income is used to cover additional expenses, such as children's pocket money and kitchen spices. This contribution by women aligns with the findings of Larson et al. (2021b), which emphasize that women's involvement in the seaweed production chain enhances household welfare and expands economic benefits.

***Seaweed Diversification with Farming*:** This pattern involves four household informants managing a joint venture that cultivates seaweed and grows rice, mung beans, yellow corn, and sticky corn. The breakdown is as follows: 25% of informants grow rice, 50% grow corn, and 25% grow mung beans. The farmers in Pandala and Ongkowa villages use their land during the rainy season to cultivate seaweed. Meanwhile, during the dry season, they move to Labborok Village (Jeneponto District) and Malelaya Village (Punanga Village) because the water flow in Laikang Bay is insufficient. A smooth flow of water is significant for seaweed to absorb nutrients optimally. Rice farming has an average area of 0.4 hectares, while corn and green beans have an area ranging from 0.2 to 0.76 hectares. Location-adaptation strategies based on seasonal variations demonstrate high utilization of natural capital. The number of ropes used is greater than in other patterns. Therefore, natural resources are given a score of 5. Family workers, including those involved in planting, fertilizing, and harvesting, manage the land. The entrepreneurs' educational backgrounds range from non-school education to elementary and junior high school. Two informants are members of farmer groups, while the other two are not. The average experience in seaweed cultivation is 14 years. The utilization of human capital assets is given a score of 4. Physical capital in the form of facilities used includes wooden/fiber boats, boat engines, and tools such as tarpaulins, drying racks, ropes, and bottles. Manual tools, such as hoes, sickles, and machetes, are used for farming, so physical capital assets were assigned a score of 3. The financial capital assets were financed through microfinance institutions, including Komida (IDR 4 million with weekly installments of IDR 100,000 for 48 weeks) and PNM, as well as capital assistance from collector traders. There is no focus on savings due to the large capital requirements, so a score of 3 is given. The use of loans as capital to purchase seeds and pay farm workers' wages, facilitated by banks and microfinance institutions, differs from Fausayana et al. (2014), which found that the provision of seaweed business capital for the Bajo community was limited to traditional institutions (punggawa). This is because the funding model offered did not meet the farmers' expectations. Social networks are more common among seedling mothers, collectors, kiosk owners, and seed suppliers. The score of 2 is based on the limited number of informants who are members of farmer groups. The combination of livelihood assets is illustrated in Figure 3.

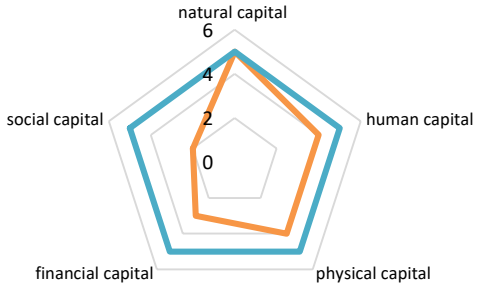

Figure 3. Combination of Asset Use, Seaweed, and Farming Patterns.

The advantage of being a member of the cultivation group is that I learn cultivation techniques. The farmland my family inherited is used to grow yellow corn and sticky rice (FDS, Seaweed Farmers and Corn Farmers).

Seaweed farming and fishing groups (Pokdakan) contribute to increasing their members' knowledge of seaweed farming techniques. Income from seaweed farming is used for various purposes: family food, capital for further seaweed farming, children's education, and the purchase of jewelry as an investment that can be pawned if necessary. From agriculture, the results of utilization differ depending on the type of crop. Rice is used for family consumption, while corn and green beans are sold and provide cash income.

***Seaweed Diversification with Fisheries Businesses*:** The pattern involved nine informants, the majority of whom (66.7%) worked as fishermen, primarily using nets, with some employing other fishing gear. In addition, 11.1% of informants developed lobster farming, and another 11.1% cultivated sea grapes. These activities were carried out in the coastal areas of the Laikang, Boddia, and Puntondo villages, which have favorable geographic conditions due to their proximity to the coast. Meanwhile, sea grape cultivation takes about three months to harvest, lobster cultivation takes almost a year, and seaweed cultivation takes 30-40 days.

Activities carried out include seaweed farming, fishing, lobster farming using cages, and opening ponds for sea grape cultivation. Although there are challenges, such as weak ocean currents in Laikang Bay, they are not a significant obstacle to cultivation. Therefore, a score of 4 is given for the utilization of natural capital as a livelihood asset. Physical capital, such as equipment like boats, is significant for fishing and aquaculture activities. Additionally, tools such as nets and fishing rods are used depending on the type of business. Seaweed uses ropes, while lobsters use cages (Diedrich et al., 2019). However, the use of equipment tends to be traditional, which is why it is given a score of 3. The use of relatively simple equipment that draws on local knowledge encourages farmers to maintain seaweed cultivation as a livelihood (Rimmer et al., 2021). Human capital, in the form of labor,

originates from households with varying levels of education (ranging from no schooling to high school). However, long work experience (2 to 30 years) suggests that skills and productivity have been refined over time. A total of 55.55% of respondents were members of farmer and fisher groups (Pokdakan), while the rest had not yet joined. The presence of extension workers and farmer groups helped increase their capacity, resulting in a score of 5. This finding aligns with the results of Riany et al. (2023), who suggest that extension programs through farmer groups can effectively enhance farmer capacity.

This group establishes relationships with external parties, such as the government, to obtain assistance, including boat engines and ropes. However, social networks are not yet optimally developed due to limited cooperation with cooperatives, seaweed associations, and the processing industry, resulting in a score of 2. Fishing and marine aquaculture activities carry high risks, so farmers primarily use bank financing (77%). Only 30% of farmers (lobster and seaweed cultivation combined) have savings. The use of microfinance institutions remains minimal, resulting in a high dependence on informal loans, as reflected in a score of 3. The combination of asset use is illustrated in Figure 4.

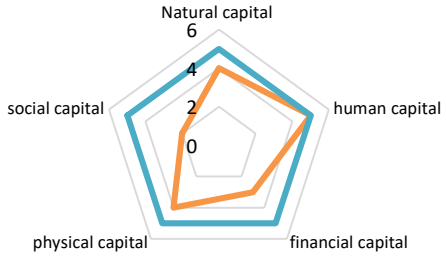

Figure 4. A combination of the use of subsistence assets in seaweed patterns and fishery businesses.

"I received assistance for a boat engine because I formed a farmer group and submitted a proposal that helped with business operations"(BS, seaweed farmer, fisherman).

Livelihood strategies are implemented through diversification, combining seaweed farming with fishing, sea grape cultivation, and lobster farming. Commonly caught fish include baronang, cepa, snapper, and crab. Income from seaweed is used for consumption, children's education, and jewelry production. On the other hand, income from fishing is used for side dishes and to increase capital for the seaweed business. Income from lobsters and sea grapes is used for food, children's education, and home renovations. Seaweed can be cultivated as a business, though small-scale (home-based) operations are best combined with fishing businesses, given that coastal areas are particularly vulnerable (Sutanto et al., 2022).

***Seaweed Diversification with Agricultural and Fishery Businesses*:** Seaweed farmers in this pattern are in Laikang, Boddia, Turikale, Pandala, and Ongkowajaya, where they combine seaweed cultivation with rice, corn, and capture fisheries farming. The proportion of business activities shows that: (1) 60% manage seaweed cultivation + rice + fisheries; (2) 20% manage seaweed cultivation + fisheries + corn; (3) 20% manage seaweed cultivation + fisheries + corn and mung beans. Seeds are obtained from farmer shops or relatives. Fishing activities are carried out in the afternoon, starting with the setting of nets at 5:00 p.m. and the collection of the catch at 6:00 a.m. After that, they continue with seaweed seedling activities. The agricultural cycle is arranged according to the seasons: rice is planted at the end of November and harvested in March; corn is planted in March and harvested in June; and green beans are grown in July and harvested in September. Fish catching at sea is a type of capture fisheries, while seaweed cultivation is often referred to as aquaculture (Gunawan, 2016). Farmers optimize land and marine natural resources with business patterns that adapt to the seasons. Business diversification is very high, reflecting a sustainable livelihood system with a score of 5. Education as a driver of human capital is demonstrated by the diversity of educational levels (elementary school, junior high school, and D2) and business experience of up to 25 years. Family involvement in the business, coupled with several farmers joining groups, indicates knowledge and management transfer, with a score of 4. Farmers work with seed suppliers, equipment suppliers, collectors, and farmer groups also serve as indicators of the strength of social networks in utilizing social capital. Therefore, a score of 3 is given. Although some utilize bank loans, most still rely on capital from previous business ventures. Access to formal financial institutions is not optimal, so a score of 2 is given. The means of production used include fishing and agricultural tools, which are part of physical capital. Although supported by mechanical equipment, it is not yet used efficiently, so a score of 3 is given. This pattern is illustrated in Figure 5, which shows the combination of asset use.

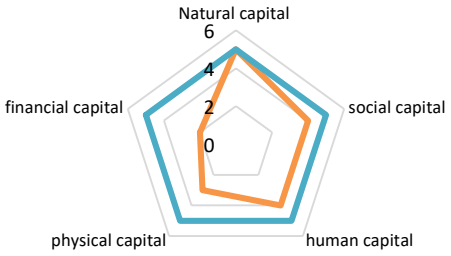

Figure 5. Combination of Seaweed Pattern Livelihood Assets with Agriculture and Fisheries Business.

"I run a seaweed cultivation business along with a fishing

business using nets and rice farming. The importance of good relationships with people for cooperation has encouraged me to form a group of seaweed farmers, fishermen, and rice farmers so that we can get assistance in the form of ropes and freezers for cooling fish" (LDT. Seaweed farmers and fishing businesses using nets and rice farming).

Livelihood strategies involve diversification, with a focus on seaweed cultivation, supplemented by rice farming for food consumption. Some engage in farming (corn and green beans) for sale to earn additional income, though this is done only once or twice a year, and yields are small because the average land area used is only about 0.3-0.5 hectares per farming household. They also catch fish with nets, catching a relatively diverse range of species, including the Holothuria scabra sea cucumber (sand sea cucumber). The livelihood obtained from seaweed is used for food consumption, children's education, jewelry, minor home renovations, and the purchase of vehicles (motorcycles). The fishing business is used for additional consumption and capital for the seaweed business, as well as social activities (weddings, circumcisions, funerals, and religious activities).

***Seaweed Diversification with Agricultural and Non-Agricultural Enterprises*:** Seaweed has high market value, though it can be subject to price fluctuations. This is the reason why seaweed is a significant business. Farmers engage in agricultural activities, as do enterprises outside the farm sector. Despite efforts to diversify non-agricultural livelihoods, the exploitation of natural capital, particularly the sea, continues, and it is also a significant source of identity for coastal communities (Cinner & Bodin, 2010). Meanwhile, non-agricultural businesses, such as seaweed collectors, kiosk owners, rice millers, mobile meatball sellers, and construction workers, are established independently. A total of 72% of farmers manage rice farming businesses, 14% grow corn and mung beans, and another 14% specialize in growing corn. In utilizing natural resources —both from the sea (through seaweed cultivation) and from the land (agriculture) — farmers scored 4.

Most of the agricultural land is owned by the farmers themselves, although one informant is a farm laborer or fisherman. The role of human resources is crucial in cultivation. Farmers use their labor and minds to manage their businesses, including agriculture, seaweed cultivation, and other non-agricultural activities. They also make decisions regarding the use of production facilities, which earned them a score of 5, and utilize family members in running the business, despite their limited education and training. According to Webb et al. (2023), Training in offshore agricultural management is crucial for enhancing farmers' skills. This remains true, even though education levels are relatively low and business experience varies. Social capital is reflected in the exchange of information about cultivation, which is generally obtained from family and neighbors, indicating strong social bonds. However, participation in cultivation groups remains low, with only one informant (14.29%) a member, while the rest (85.71%) are not yet members. Therefore, this social capital is given a score of 3.

Regarding physical capital in the form of production tools, several farmers already own boats. Farmers who do not yet own boats choose to rent and use floats. This demonstrates an effort to provide operational equipment, earning it a score of 4. Regarding financial capital, most of the financing for seaweed farming activities comes from non-agricultural business income. Therefore, dependence on financial institutions such as banks and microfinance institutions is relatively low. They also generally have savings, so the use of financial capital is rated at 2. The combination of capital assets is illustrated in Figure 6.

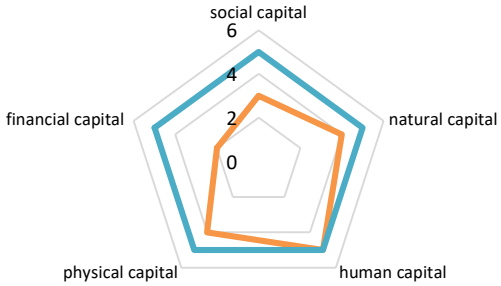

Figure 6. A combination of seaweed pattern livelihood assets with agricultural and non-agricultural businesses.

"I have been running a seaweed business for the past three years in Laikang Village, right behind my house, both during the rainy and dry seasons, in addition to rice farming. I also opened a rice milling business, but not in the form of" money," but in the form of rice. If I mill 10 liters, I will receive 1 liter, and if I mill 30 liters, I will receive 3 liters." (TD. Seaweed farmer, rice farmer, and rice milling business

The livelihood strategy employed by cultivators involves diversifying their income by combining seaweed production with agricultural businesses and investing their capital in non-agricultural ventures. The livelihood of seaweed: consumption, children's education, jewelry, building houses, and buying motorcycles and cars. Meanwhile, income from the agricultural business is primarily used for food, side dishes, and household expenses. The proceeds from non-agricultural companies will be used to strengthen business capital, support seaweed businesses, fund social activities, and increase food consumption.

***Seaweed Diversification with Non-Agricultural Businesses*:** The types of non-agricultural work carried out by informants include construction labor (23.1%), frame making (7.7%), traveling meatball vendors (7.7%), running food stalls (7.7%), workshops (7.7%), fruit vendors (7.7%), boat builders (7.7%), seaweed traders (15.4%), barbers (7.7%), and lobster traders (7.7%). The diversification of these jobs is relatively high, although they are generally informal and based in households. Most

farmers initially worked in the non-agricultural sector, then switched to seaweed farming after witnessing the success of their relatives or neighbors, indicating a strong social motivation. Human capital is an essential asset in exploring: knowledge, skills, physical abilities, and financial resources (Habib et al., 2023). Some farmers suspended their activities due to unfavorable ocean currents, resulting in a score of 3. Although many have experience in this business (3-30 years), only a few are members of farmer groups (23%), indicating low participation in organizations and access to information. Therefore, it was given a score of 4. Social networks are an essential factor in the seaweed business (seed procurement, capital, marketing) and in other companies, such as service and trade companies, to support economic sustainability.

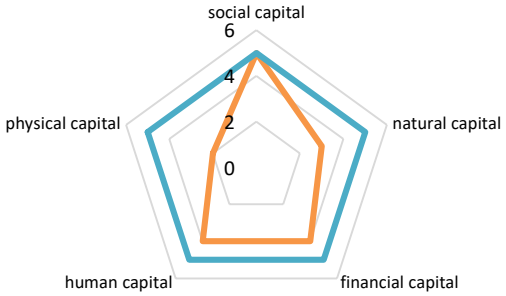

Figure 7. A combination of the use of seaweed pattern livelihood assets and non-agricultural businesses.

The importance of social capital for farmers was rated 5. While income from informal work fluctuates, capital for the seaweed business is highly dependent on financial institutions, especially for seed purchases and labor payments. However, specific non-agricultural work can also support seaweed capital, so it was given a score of 3.

Table 1. Comparison of the Subsistence System in Seaweed Farming Households.

No.	Description	Pattern of livelihood diversification					
		1	**2**	**3**	**4**	**5**	**6**
1.	natural resources	Sea	Sea and land (rice fields and gardens)	Marine (fishing, lobster, sea grapes)	Marine and territorial resources	Sea and land (rice fields and gardens)	Sea
2.	Use of seedlings	Spinosum	*Euchema cottoni*, Spinosum	*Euchema cottoni*, Spinosum	*Euchema cottoni*, Spinosum	*Euchema cottoni*, Spinosum	*Euchema cottoni*, Spinosum
3.	Ownership of agricultural land	Not available	Personal	Personal	personal	Personal and Revenue sharing	Not available
4.	Average number of stretches	181	450	277	272	302	375
5.	Extension	Not yet available	Available	Available	Not yet available	available	Not yet available
6.	cultivation groups	Not yet a member	Not yet 50% incorporated, 50% incorporated	Unincorporated (45%), Incorporated (55%)	Not yet a member (60%) Incorporated (40%)	Unincorporated (86%), Incorporated (14%)	Unincorporated (77%), Incorporated (23%)
7.	Ownership of equipment	Used boats, Boat engines	Boats, boat engines, farming tools (scythes, machetes, sprayers, tools for growing rice)	Boat Boat engine Dragnet Fishing gear Cages	Boat Boat engines, Fishing nets, Crab nets, Tools in farming	Boats, boat engines, tools used in farming, and equipment used in non-agricultural businesses	Boats, boat engines, equipment owned for non-agricultural businesses
8.	Savings	Available	Not yet available	Quite available	available	available	Not yet available
9.	Access loans	Microfinance Institutions, Collector trader	Bank, Microfinance institutions	Bank, Microfinance institutions, Collector trader	Bank, Microfinance institutions Collector trader	bank Microfinance institutions, Collector trader	Bank, Microfinance institutions, Collector trader
10.	Degree of Diversification	Low	Quite tall	Quite tall	tall	tall	Quite tall

The equipment used in the seaweed business tends to be uniform. In contrast, for non-agricultural work, the equipment is more diverse, depending on the type of work carried out, and therefore received a score of 2—utilization of livelihood assets in pattern six in Figure 7.

"I cultivate seaweed in the Puntondo area (rainy season) and Santigia on the border of Jeneponto (dry season) to run this business throughout the year due to natural conditions in the form of changing seasonal patterns" (AM, seaweed farmers, and marine product collectors).

The livelihood strategy is implemented by diversifying both agricultural and non-agricultural businesses. As for the results of living from seaweed: paying bank installments, educating children, building houses, buying vehicles (motorcycles), and there are even cultivators who can buy cars that can be used as operational vehicles to transport seaweed or sea grapes. Meanwhile, the proceeds from non-agricultural livelihoods are used to increase family income.

***Comparison of the Alimony System*:** The livelihood diversification pattern consists of six types: seaweed cultivation as a single livelihood; seaweed cultivation combined with farming; seaweed cultivation combined with fishing; seaweed cultivation businesses; seaweed cultivation combined with farming and fishing; seaweed cultivation in agriculture or a combination of agriculture and non-agriculture; and seaweed cultivation in non-agriculture. Each type has its own characteristics and differences, so a comparison of livelihood systems was carried out, which is presented in Table 1.

Managing seaweed-based businesses: involving husbands, wives, and children. Most agricultural land is privately owned through inheritance or purchase; however, one category uses a profit-sharing scheme. The more diversification is carried out, the more equipment is used. Diversification consists of three businesses, which serve as a savings function and provide investment opportunities through trading activities.

DISCUSSION

***Institutional Influence (government policies, market mechanisms, community/farmer group institutions, and Social Interaction on Livelihood Diversification)*:** The government distributes aid to farmers through Joint Business Groups (KUB) and Fish Farming Groups (Pokdakan), including ropes of sizes 7 and 10, as well as boat engines. This aid helps reduce long-term production costs, especially those related to equipment procurement, allowing farmers to cultivate optimally.

The existence of farmer groups also provides access to extension services, which play a strategic role in disseminating information, improving human resource capacity, and boosting the productivity and income of business actors (Attipoe et al., 2021). This is key to maintaining the sustainability of aquaculture (Erasmus et al., 2025). In 2024, extension activities focused on pests and diseases affecting seaweed commodities. Although most groups have received assistance from extension officers, counseling implementation has not been optimal. This is because most farmers in Laikang Village are still beginners, with a membership period of only one year.

Commodity price fluctuations occur temporally due to the dynamics of supply and demand (Suganda et al., 2024). This phenomenon is reflected in the price of seaweed, which has fluctuated significantly, ranging from IDR 45,000/kg in August 2022 to IDR 13,000/kg in March 2025. These price fluctuations are caused, among other things, by farmers' dependence on collectors as the main channel for distributing their harvest. Price fluctuations pose a significant obstacle to poverty alleviation efforts in developing countries, such as Indonesia (Mekasha et al., 2022), as they directly impact the long-term financial stability of farming households. When production costs exceed income due to changes in selling prices, farmers incur losses, thereby increasing their economic vulnerability. Therefore, effective business management and diversification strategies are crucial for preserving water resources and enhancing community income. Diversification also includes non-agricultural sectors, which generate revenue through salaries, wages, or daily work (Hanh, 2021; Wiebe et al., 2022). In practice, seaweed is sold through collectors who regularly collect the harvest from farming households. Before being sold, it undergoes a traditional drying process (drying in direct sunlight). In contrast, Malaysia has adopted solar-based drying technology integrated with a photovoltaic (PV) system, making it more efficient and providing greater economic value to farmers (Khan et al., 2025). After collection, the goods are taken to the Makassar Industrial Area (KIMA) and sold directly to wholesalers without further processing. Processing facilities at the provincial level are crucial to overcoming marketing barriers and increasing product added value, thereby strengthening the competitiveness of seaweed in the market (Langford et al., 2023).

The conflict of interest over land use for seaweed cultivation in Laikang Village arose because long-time farmers claimed the land as their private property and passed it down to subsequent generations. As a result, new farmers have difficulty obtaining land and running their businesses up to the border between Takalar and Jeneponto. In addition, high rainfall has also encouraged the relocation of cultivation to other villages. This further narrows the opportunities for different households in the town to participate in seaweed cultivation. Conflicts over land use and investment, such as this, are also found in African countries, where they can even lead to violence. The impact hinders agricultural production, damages people's livelihoods, and significantly contributes to poverty (Amare et al., 2025). Competition exists between banks and microfinance institutions in distributing credit to

seaweed cultivation businesses. Banks try to attract farmers by offering low-interest rates on loans (Lei et al., 2024). On the other hand, microfinance institutions offer convenience through unsecured loans and relatively small loan amounts, making installments lighter and more affordable (Chandio et al., 2021). On the other hand, cultivators are also competing for access to simple technology, such as boats, to support their businesses. To meet these needs, they use services from banks and microfinance institutions (Mariyono, 2019).

Meanwhile, existing cooperation has been local in nature and limited to information on seeds, nurseries, and other business techniques (rice, corn, and mung bean farming). On the other hand, China has established agricultural cooperation with African countries in food crop production, encouraging increased production and positively impacting local agriculture and rural development (Lin & Cui, 2024). National and international coordination and partnerships need to be enhanced to develop a fair and sustainable agriculture and fisheries sector.

In seaweed cultivation practices, a division of labor is based on gender. Women play a role in the early stages, such as tying seedlings to ropes, and in the post-harvest stage, specifically the drying process. Meanwhile, men are responsible for cultivation activities, including marketing and decision-making. Although women's roles in the cultivation process are recognized, their participation in strategic decision-making remains minimal. These obstacles are closely related to cultural norms. Women's overall participation can positively impact the sustainability of resource management. Interestingly, a different situation is observed in household-level forest management and in community forest programs. Based on findings, Ota et al. (2024) found that women are increasingly actively participating in the decision-making process. Their participation has been shown to increase the effectiveness of forest management. Therefore, responsive gender-inclusive policies are needed. This step aligns with the Sustainable Development Agenda, particularly in its efforts to achieve gender equality and sustainable marine management. Women's empowerment has a significant impact on social justice and improves the overall effectiveness of resource management (Mengo et al., 2023). In this context, women are equipped with skills through training and broader access to employment opportunities, particularly in seaweed product processing.

***The Influence of Vulnerability Context on Livelihood Diversification*:** Vulnerability context encompasses risks from economic, social, and environmental perspectives, as well as the ability to cope with events (Proag, 2014). Coastal communities suffer severe livelihood losses due to climate change. Evidence regarding social and economic vulnerability is summarized in Table 2.

Table 2. Context of Economic, social, and ecological vulnerability.

No.	Vulnerability Context	Shape
1.	Economics	- Decreased quality and reliability due to pest and disease attacks - Decrease in selling price - Crop failure - Decreased income
2.	Social	- Land Use
3.	Ecology	- Deterioration in the quality of the coastal environment - Deterioration of water quality - Changes in the rainy cycle and dry season

Seaweed cultivation is susceptible to pests and diseases, which can reduce production and the quality of the harvested product. In Laingkang Village, cases of epiphyte infection have been reported, characterized by small organisms, such as algae and macroinvertebrates, attaching to seaweed tissue. According to Usandizaga et al. (2025), an epiphyte infection can cause biomass loss or even the total death of the host seaweed. Additionally, the ice-ice syndrome phenomenon poses a significant threat. This syndrome is triggered by fluctuations in salinity, increases in sea temperature, and pest attacks, causing the seaweed thalli to change color from green to white. As a result, the quality of seaweed declines, reducing its market value (Kambey et al., 2021). The type of seaweed most commonly affected by ice is Euchema cottoni, which produces consistency (Bhuyan, 2023). Rising temperatures, which impact livelihoods, increase vulnerability to climate change (Arifah et al., 2022). Therefore, counseling and technical guidance are needed to address this issue. The available land has been taken over by farmers who first started seaweed farming in the Laikang area. Meanwhile, new farmers in the village must find planting locations farther away because of limited land, which results in additional transportation costs. In addition, during the dry season, weak water currents force farmers to move to Santigia and Punanga for more favorable conditions. As a result, they have to bear additional costs, including land rent. This condition results in limited available land and the potential for competition for space. To overcome this problem, according to Basyuni et al. (2024), more targeted spatial planning and zoning are needed for seaweed cultivation areas. Thus, cultivation practices can be carried out sustainably, reducing the potential for conflict between marine space users and ensuring smooth traffic in the surrounding waters. Climate change has a significant impact on coastal areas worldwide, including Laikang Village. This impact is evident in the warming trend across the dry season, which facilitates the emergence of diseases like ice-ice, and in the high rainfall that affects seaweed growth. Therefore, increasing public awareness of climate adaptation strategies

and risk management is crucial (Chambon et al., 2024). Access to information on temperature and rainfall changes is necessary to design and implement the most effective strategies, including seed selection and optimal planting times (Abawiera Wongnaa et al., 2024).

The ecological vulnerability caused by using plastic in seaweed cultivation harms the marine environment. Plastic waste, including ropes and floats, often pollutes coastal ecosystems. As a result, marine life, especially coral reefs, is damaged, as they are sensitive to pollution. In addition, aquatic animals, especially fish, ingest plastic, ultimately causing death. Plastic waste also affects water quality in cultivation areas, impacting seaweed growth and resulting in suboptimal yields, which threaten marine life and the sustainability of seaweed production. Microplastic contamination poses a new challenge in the development of sustainable aquaculture (Basyuni et al., 2024). A viable solution is to replace conventional plastic with seaweed-based alternatives. These bioplastics are biodegradable and environmentally friendly, and can also help reduce greenhouse gas emissions (Zhang et al., 2024).

Reducing vulnerability is necessary to improve the community's social and demographic conditions, strengthen social networks (Saha et al., 2024), and develop alternative livelihoods (Khanal et al., 2024). In addition, access to inclusive financial services is also key to strengthening their economic resilience (Sisay, 2024).

***Conclusion*:** This study found that households that rely on seaweed cultivation as their main livelihood are vulnerable to price fluctuations and environmental disturbances. On the other hand, those who diversify their economic activities into agriculture, fisheries, and other sectors reap benefits: increased income and strengthened household financial stability. This additional income is used to meet daily needs, reinvest in seaweed businesses, or develop new businesses. This research offers a comprehensive understanding of coastal livelihood systems, with a particular focus on seaweed cultivation. These findings are expected to form the basis for developing sustainable policies to promote the economic empowerment of seaweed farmers.

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***Availability of data*:** The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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***Policy referred*:** Indonesia's National Medium-Term Development Plan (RPJMN 2020-2024); Ministry of Marine Affairs and Fisheries (KKP).

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